REFERENCE: Lesschen, J.P., W. Elbersen, R. Poppens, M. Galytskaya, M. Kulyk and L. Lerminiaux. The financial and GHG cost of avoiding ILUC in biomass sourcing - A comparison between switchgrass produced with and without ILUC in Ukraine. *In.* Eur. Biomass Conf. June 18-23 2012. Milan.

THE FINANCIAL AND GHG COST OF AVOIDING ILUC IN BIOMASS SOURCING - A COMPARISON BETWEEN SWITCHGRASS PRODUCED WITH AND WITHOUT ILUC IN UKRAINE

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ABSTRACT: Biomass production has both direct effects and indirect effects. Direct effects such as the energy balance and GHG balance can be directly measured, to make sure that impacts are (significantly) below the fossil fuel comparator. In recent years it has also been recognized that the production and use of biomass for energy has indirect effects which are caused by competition for inputs and land. The most important indirect effect is ILUC (indirect land use change) and the associated GHG emissions, which have been quantified in different studies. Avoiding ILUC is now becoming important. An important option is the use of land that would otherwise not be used for food or feed production. This generally means that lower quality or marginal land will be used. Switchgrass is one of the main perennial biomass crops that can produce high biomass yields under low input conditions and which can be established at low cost by seeds. In Ukraine this crop has in recent years been tested, yielding information that can be used to assess the cost and GHG balance of growing the crop, pelletizing, transport to the Netherlands and conversion into electricity. Results show that GHG emissions on low quality soil without ILUC (12.5 g CO_2 MJ^{-1} pellet) are higher than for good quality soil grown switchgrass with ILUC (0.1 g CO_2 MJ^{-1} pellet). Analysis of the costs of growing switchgrass on low productive soils are 22% higher compared to high quality soils. We conclude that ILUC avoidance needs to be quantified and rewarded.

Keywords: costs, greenhouse gases (GHG), land use, pellet, switchgrass

1 INTRODICTION

Biomass production has both direct effects and indirect effects. Direct effects (within the production chain) such as the GHG balance and impact on e.g. soil and air, can be directly measured to make sure that impacts are within limits, or significantly better than the fossil fuel comparator in the case of GHG balance. Criteria have been established to ensure this (RED, 2009). In recent years it has been recognized that the production and use of biomass for energy can also have significant *in*direct effects which are caused by competition for inputs and land. The most important indirect effect is ILUC (indirect land use change) and the associated GHG emissions. [1] showed that the GHG emissions associated with ILUC can be very significant. Since then a number of studies, mainly focusing on ethanol and biodiesel, have shown that ILUC associated GHG emissions can be very significant and can even be larger than the fossil fuel comparator [2][3]. The discussion on how to avoid ILUC has barely started and few studies mentioning strategies exist [4] and [5]. One strategy is to use land and biomass more efficiently, i) through the use of unused and underutilised by-products, such as straw and other crop residues, or biomass from nature (e.g. reed), ii) by increasing the productivity per hectare, iii) by using multi-purpose crops or iv) through biorefinery and cascading of biomass. Another obvious strategy mentioned is to use land for biofuel feedstocks which is not competing with other uses. This will generally mean that marginal land has to be used which is currently not used for crop production (or other uses).

In this study we compare the economic cost and the GHG balance of biomass production in Ukraine for switchgrass (*Panicum virgatum* L.) on good quality land which was previously used for other crop production, and switchgrass production on low quality land which is currently not used for crop production. We assume that GHG emissions due to ILUC are significant in the second case and non-existent on the marginal/abandoned low quality land. This should lead to an answer for our research question: what is the financial and GHG cost of avoiding ILUC?

2 SWITCHGRASS

Switchgrass (*Panicum virgatum* L.) is a perennial C_4 grass native to North America. The grass has been developed as a biomass crop in the USA since the 1980's and has also been studied in Europe since the 1990's [6]. As biomass increases in importance in Ukraine it is expected that switchgrass can play an important role in supplying sustainably produced lignocellulosic biomass.

Switchgrass is seeded which makes establishing large fields relatively inexpensive compared to *Miscanthus* which is propagated by rhizomes. Switchgrass is deep rooting, often more than 2 m and grows 50 to 250 cm tall depending on variety and climatic conditions. It has the C4 photosynthetic pathway which leads to efficient use of nutrients (nitrogen, phosphate) and water. This makes it potentially a very productive and efficient biomass crop. If properly managed it has long-term productivity potential (>15 years) with a high level of sustainability. Switchgrass has been tested in Ukraine since four years on good and lower quality soils. The first results of these tests have been used to estimate yields and inputs for this study.

3 DESCRIPTION OF THE TWO SWITCHGRASS PRODUCTION CHAINS

We compared the production of switchgrass for pellet production at two sites in Ukraine, Veselyi Podil in Poltava Oblast and Yaltushkiv in Vinnytja Oblast.

In Table I the basic conditions and assumptions for both selected sites are described, which were used for input in a model to calculate the cost of biomass delivery to a pelletizing facility and to calculate the GHG emissions for the pellets when delivered for electricity production.

We assumed that switchgrass was produced in the vicinity of a pelleting plant with a production capacity of 40,000 tons of pellets per year. At the high productive site (Veselyi Podil) we assumed a final yield of 12 tons DM per ha after 4 years and in the lower productive site (Yaltushkiv) the final yield was assumed 7 tons DM per ha after 4 years. This was based on harvesting in winter when most nutrients have been translocated belowground and K, Na and Cl have been largely leached out. This improves biomass quality for thermal conversion.

Table I. Comparison of high and low productive switchgrass sites in Ukraine

	High productive Veselyi Podil	**Lower productive Yaltushkiv**
Climate	Cool dry	Cool dry
Topography	Flat	Rolling
Land degradation	Few saline soils	Acid soils
Soil type	Chernozems	Phaeozems
SOC_{REF} stock (ton C/ha)	117 ton C/ha	86 ton C/ha
Unused / abandoned land	~2%	~25%
Switchgrass yield	12 ton/ha	7 ton/ha
Avg. distance to pelletizer	7.1 km	13.2 km

We assumed the production would meet sustainability requirements such as defined in the RED and NTA8080 standards [7]. This meant, among other, that equilibrium fertilization was applied meaning that fertilization was equal to nutrient removal. We assumed a 15 year plantation life and that final maximum yield was reached after 4 years. For the high productive site (Veselyi Podil) we assumed that all the fields were close to the pellet plant leading to an average field to pellet plant transport distance of 7.1 km. For the low productive site we assumed that 25% of the (marginal land) area surrounding the pellet plant is used for switchgrass production, leading to a longer average transportation distance of 13.2 km.

4 COST AND GHG CALCULATIONS

Input and yield levels were estimated based on [6] and the switchgrass manual for Ukraine [7]. For calculation of the GHG emissions and the cost of switchgrass delivery we used local data generated in the project and data from [6]. Land rents were assumed €20 and €40 per ha per year, for low and for high quality land respectively. Interest rates were not taken into account.

The GHG balance was calculated according to the RED 2009/28/EC formula:

$$\mathbf{E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}}$$

E	total emissions from the use of the fuel;
e_{ec}	emissions from the extraction or cultivation of raw materials;
e_l	annualised emissions from carbon stock changes from land use change;
e_p	emissions from processing;
e_{td}	emissions from transport and distribution;
e_u	emissions from the fuel in use;
e_{sca}	emission saving from soil carbon accumulation via improved agricultural management;
e_{ccs}	emission saving from carbon capture and geological storage;
e_{ccr}	emission saving from carbon capture and replacement
e_{ee}	emission saving from excess electricity from cogeneration

Relevant emissions for this study are the emissions from cultivation, emissions from carbon stock changes from land use change (conversion of abandoned land to switchgrass), emissions from processing and transport and distribution and emission savings from soil carbon accumulation via improved agricultural management (i.e. cultivation of perennial switchgrass instead of rotational arable crops). Activity data were obtained from the local switchgrass experiments and Emissions factors were based on the BioGrace standard values [8].

Calculation of soil organic carbon (SOC) stock changes was performed according to IPCC 2006 guidelines [9]:

$$\mathbf{SOC = SOC_{REF} * F_{LU} * F_{MG} * F_I}$$

SOC_{REF}	reference carbon content of the soil (ton C ha^{-1})
F_{LU}	stock change factor for land use
F_{MG}	stock change factor for management
F_I	stock change factor for input crop production

Switchgrass as perennial crop and its deep rooting system can sequester significant amounts of carbon in the soil. Table II shows that SOC on the high quality soil can increase from 93 ton C ha^{-1} under arable land to 119 ton C ha^{-1} under switchgrass. On the lower quality soil, the increase is lower, from 80 ton C ha^{-1} under abandoned land to 88 ton C ha^{-1} under switchgrass. IPCC assumes a 20 year period to reach a new equilibrium in soil carbon stocks, which is also the period we used to convert to annual CO_2 emissions.

Table II. Calculation of soil organic carbon stocks for arable land, switchgrass and abandoned land

	F_{LU}	F_{MG}	F_I	High quality soil		Lower quality soil	
				SOC_{REF}	SOC	SOC_{REF}	SOC
Arable land	0.80	1.00	1.00	117	93		
Switchgrass	1.00	1.02	1.00	117	119	86	88
Abandoned land	0.93	1.00	1.00			86	80

5 RESULTS

The cost of switchgrass delivery to the pellet plant was estimated at €52 per ton pellet under low productive conditions (without ILUC) and €42 per ton pellet under high productive (with ILUC) conditions (Figure 1). This implies that the economic cost of biomass without ILUC is 22% higher. The difference in cost was mainly due to higher cost of field operations per ton switchgrass of €6.81 for the low productive conditions versus €3.97 for the high productive conditions. Also the transport cost was 44% higher for the chain based on low productive abandoned land. The cost for pelletisation for both chains is estimated at €33 per ton pellet and €48 for transport to a co-firing power plant in The Netherlands. The overall delivery cost is € 133 per ton pellets for the ILUC free pellet chain based on marginal land, versus €123 per ton pellet for the chain based on good land (with ILUC). These cost are comparable to current wood pellet prices. Overall, the cost of avoiding ILUC in this case is €10 per ton of pellet or €0.59 per MJ pellet.

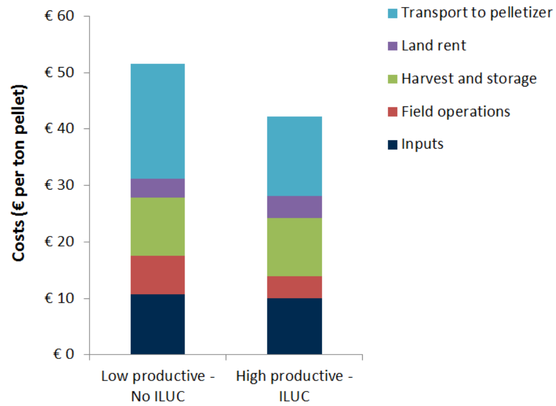

Figure 1. Delivery cost of switchgrass under low productive conditions without ILUC and under high productive conditions (with ILUC)

The GHG emission for pellet production, including cultivation, pelletising and delivery to a co-firing power plant in the Netherlands was 12.5 g CO_2-eq MJ^{-1} pellet for the low productive production chain without ILUC and 0.1 g CO_2-eq MJ^{-1} for the high productive condition with ILUC (Figure 2). This did not include the (unknown) GHG emission due to ILUC. The emissions of crop production, pelletisation and logistics were partially mitigated by soil C sequestration for the low productive conditions and completely mitigated under high productive conditions.

The GHG emission from the fossil fuel comparator for solid biomass for electricity production is 198 g CO_2-eq/MJ electricity is used [10]. Assuming a 44% conversion efficiency for electricity generation, the switchgrass pellets have a GHG balance that is between 86% and 99 % better than its fossil fuel equivalent.

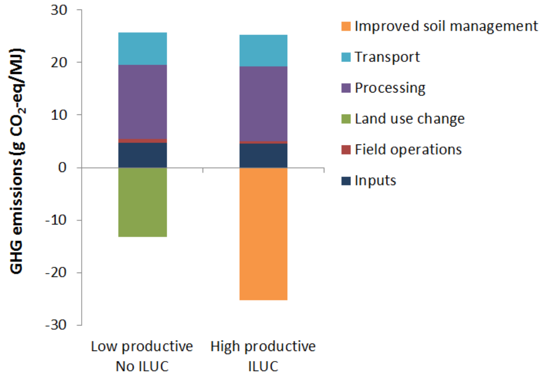

Figure 2. GHG emissions per MJ of pellet produced in Ukraine, including pelletisation and delivery to a coal plant in the Netherlands for high and low productive (with ILUC) conditions

6 DISCUSSION AND CONCLUSION

The increased cost of avoiding ILUC is estimated at 22% for the production of switchgrass or €0.59 per MJ pellet. In absolute terms, this cost difference is rather small, because establishment cost for switchgrass is low (€300/ha). For a crop with higher establishment cost, such as Miscanthus (>€2000 ha^{-1} establishment cost), both the relative and absolute cost of avoiding ILUC will be higher. The same holds for rotational crops, since the yield decline on marginal soils will be higher.

The GHG cost of avoiding ILUC will be case and location specific as soil carbon stock changes have a large effect on the GHG balance. Overall, the analysis shows that switchgrass pellets have a GHG balance that is between 86% and 99% better than its fossil fuel equivalent, mainly due to soil carbon sequestration by switchgrass. The GHG cost of avoiding ILUC is in this case 12.5 g CO_2-eq MJ^{-1} pellet delivered to a co-firing plant. Per MJ of electricity this would be approximately 28.4 g CO_2-eq MJ^{-1} electricity.

Under the RED (2009/28/EC) if soil is classified as 'degraded land' a bonus of 29 g CO_2-eq MJ^{-1} biofuel might be subtracted for 10 years. This bonus is no incentive for switchgrass, as GHG balance is already very positive, but costs on degraded soil (with no ILUC) will be higher.

To conclude we demonstrated that avoiding ILUC increases GHG emissions, but the overall GHG balance is still very positive for switchgrass. Our results also support the view that increasing the GHG balance improvement compared to fossil fuel sec is not a good option for mitigating the GHG emissions associated with ILUC.

Economic cost of avoiding ILUC is at least 20% higher, for other crops it will be higher, as establishment cost and yield depression are larger. Demanding a higher GHG balance without financial compensation will lead to not using low productive land, which reduces the totally available land for biomass production.

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8 ACKNOWLEDGEMENTS

The study presented here is part of the Pellet for Power project carried out in Ukraine, which has been partially funded by NL Agency under the DBI programme. The objective of the project is to develop a business model for producing ILUC free certified sustainable biomass pellets in Ukraine for export markets and for local fuel production.